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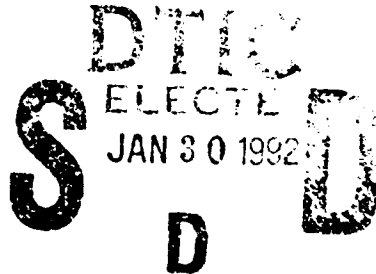
PL-TR-91-2191 (III)

THE DESIGN, DEVELOPMENT AND TEST OF BALLOONBORNE
AND GROUND BASED LIDAR SYSTEMS
Volume 3: Groundbased Lidar Systems

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1 June 1991

Final Report
30 May 1986-31 December 1990

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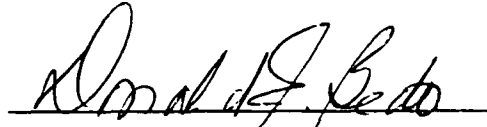
92-02340



This technical report has been reviewed and is approved for publication.



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REPORT DOCUMENTATION PAGE			Form Approved OMB No 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302 and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE 1 June 1991	3. REPORT TYPE AND DATES COVERED Final - 5/30/86 - 12/31/90		
4. TITLE AND SUBTITLE The Design, Development, and Test of Balloonborne and Groundbased Lidar Systems, Volume 3 - Groundbased Lidar Systems		5. FUNDING NUMBERS F19628-86-C-0105 PE 62101F PR 7670 TA 16 WUAA		
6. AUTHOR(S) O. Shepherd, G. Aurilio, R.D. Bucknam, A.G. Hurd, N.F. Robertie, and W.H. Sheehan				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Visidyne, Inc. 10 Corporate Place South Bedford Street Burlington, MA 01803		8. PERFORMING ORGANIZATION REPORT NUMBER VI-1707-C		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Phillips Laboratory Hanscom AFB, Massachusetts 01731-5000 Contract Manager: R. Swirbalus/OPA		10. SPONSORING / MONITORING AGENCY REPORT NUMBER PL-TR-91-2191 (III)		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; Distribution unlimited			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This is Volume 3 of a three volume final report on the design, development and test of balloonborne and groundbased lidar systems. Volume 1 describes the design and fabrication of a balloonborne CO ₂ coherent lidar payload to measure the 10.6 μ m backscatter from atmospheric aerosols as a function of altitude. Volume 2 describes the August 1987 flight test of Atmospheric Balloonborne Lidar Experiment, ABLE II. In this volume we describe groundbased lidar development and measurements. a. A design was developed for installation of the ABLE lidar in the GL rooftop dome. b. A transportable shed was designed to house the ABLE lidar at various remote measurement sites. c. Refurbishment and modification of the ABLE lidar were completed to permit groundbased lidar measurements of clouds and aerosols. d. Lidar field measurements were made at Ascension Island during SABLE 89. e. Lidar field measurements were made at Terciera, Azores during GABLE 90. These tasks have been successfully completed, and recommendations for further lidar measurements and data analysis have been made.				
14. SUBJECT TERMS Groundbased lidar, Cloud and sky backscatter, Lidar field measurements, Neodymium:YAG laser, Dome installation design, Transportable lidar shed design			15. NUMBER OF PAGES 56	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR	

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1. INTRODUCTION

In addition to the balloonborne measurements, a requirement exists for the capability to make groundbased lidar measurements of low altitude aerosols and clouds. To meet this requirement the following tasks associated with groundbased lidar were completed:

1. We developed a plan for installing the ABLE lidar system in a telescope dome.
2. We designed a transportable shelter to permit the ABLE system to be operated at a variety of remote sites.
3. Groundbased lidar measurements of aerosols and clouds for the SABLE 89 program were conducted at Ascension Island in July and August 1989.
4. Groundbased lidar measurements of aerosols and clouds for the GABLE 90 Program were made at Terciera, Azores in August 1990.

Detailed descriptions of the ABLE lidar system and its operation as a balloonborne payload can be found in References 1 and 2 and in Volume 2 of this final report.

2. ABLE DOME INSTALLATION

A plan was developed to install the ABLE lidar system in a telescope dome which is mounted on the roof of Building 1105 at AFGL. The lidar system would be removed from the ABLE payload and mounted on a bench in the dome. The dome is 15 ft in diameter and measures 12 ft 8 in. in height. It is made of ribbed galvanized steel, and the floor is a smooth cement slab. The configuration of this installation is shown in Fig. 1. The receiver telescope would view the lidar return signals through the existing 40-inch wide observation opening, which subtends an elevation angle of 90° . For making lidar measurements at four different elevation angles, the laser transmitter, which is offset from the receiver by one meter, would require the installation of 4 special openings into the dome surface. A typical opening installation is shown in Fig. 2.

There are three 3/4-in. diameter fastening bolts mounted in the middle of the floor at the corners of a triangle measuring 36.5 in. on a side. A 6-inch diameter opening in the floor can be used to feed electrical cables from the lidar down to the CAMAC data system and computer. There is sufficient 115 Vac power available for lidar operation.

A frame has been designed that has the same bolting interface as the gondola of the ABLE III payload. In this way the components can be mounted without modification from the gondola to the frame. The payload cables can also be used, except for the cables to the CAMAC data system computer. The frame would provide a stable support for the transmitter and the receiver, keeping the laser and the telescope 41 in. apart, the same distance that is found on the gondola.

The frame is designed so that it could be carried up to the roof and into the dome through the existing door. In the dome three longitudinal elements would be bolted to the cross members to form the platform on top of which the optical elements (laser, pointing system, telescope, and detectors) would be assembled. Special care has been taken to make sure that the drive system can be removed from the gondola and reassembled to the new frame without modifications.

Under the optical table there are shelves with room for the laser power supplies and ancillary electronic equipment. The CAMAC system and computer will be located in the room below the dome area. For eye safety and to avoid cross talk between transmitted laser pulse and the incoming signal to the receiver, the laser beam would be enclosed in a shroud around the laser pointing mirror. From the shroud to the dome's roof a telescoping tube contains the laser beam.

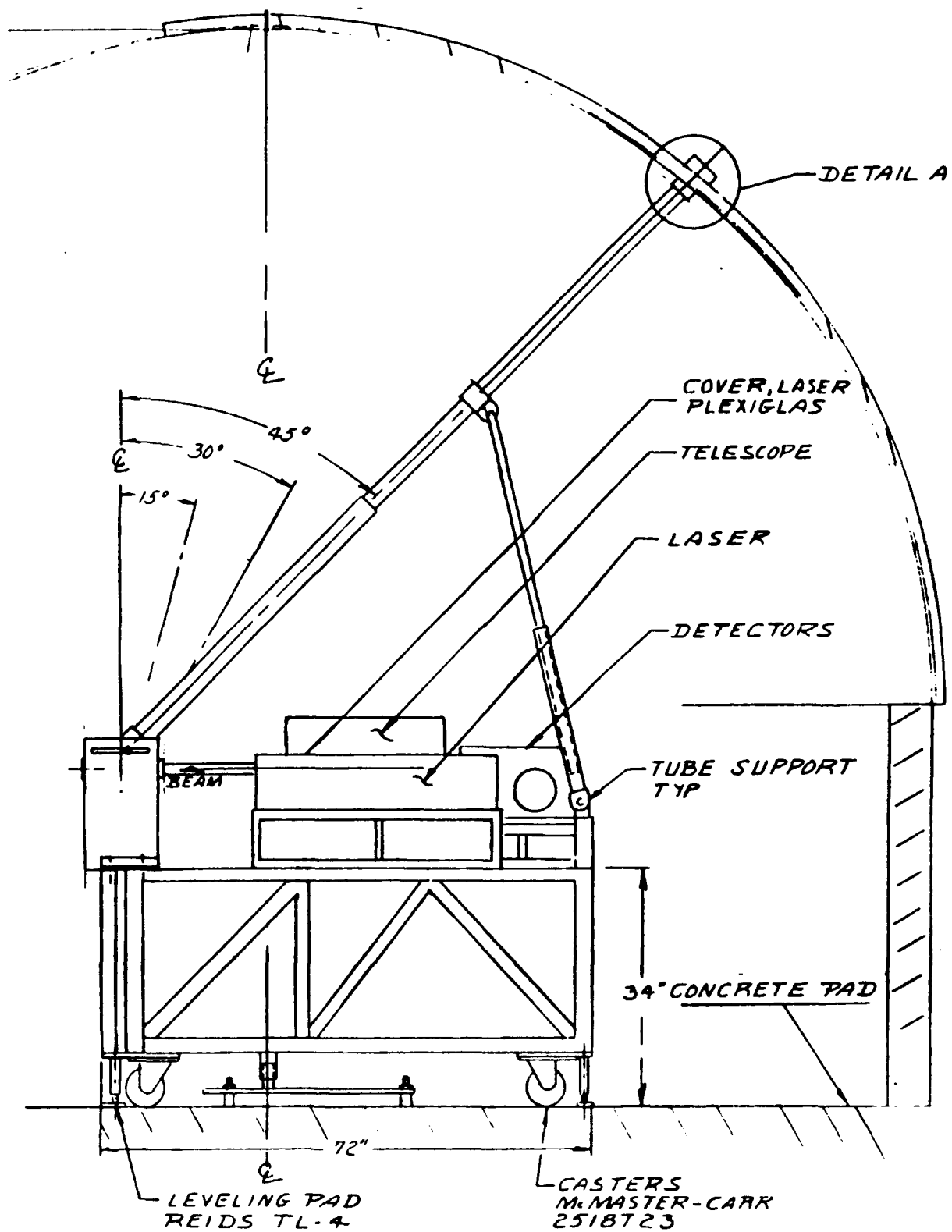


Figure 1. Mounting configuration for ABLE lidar system in AFGL dome.

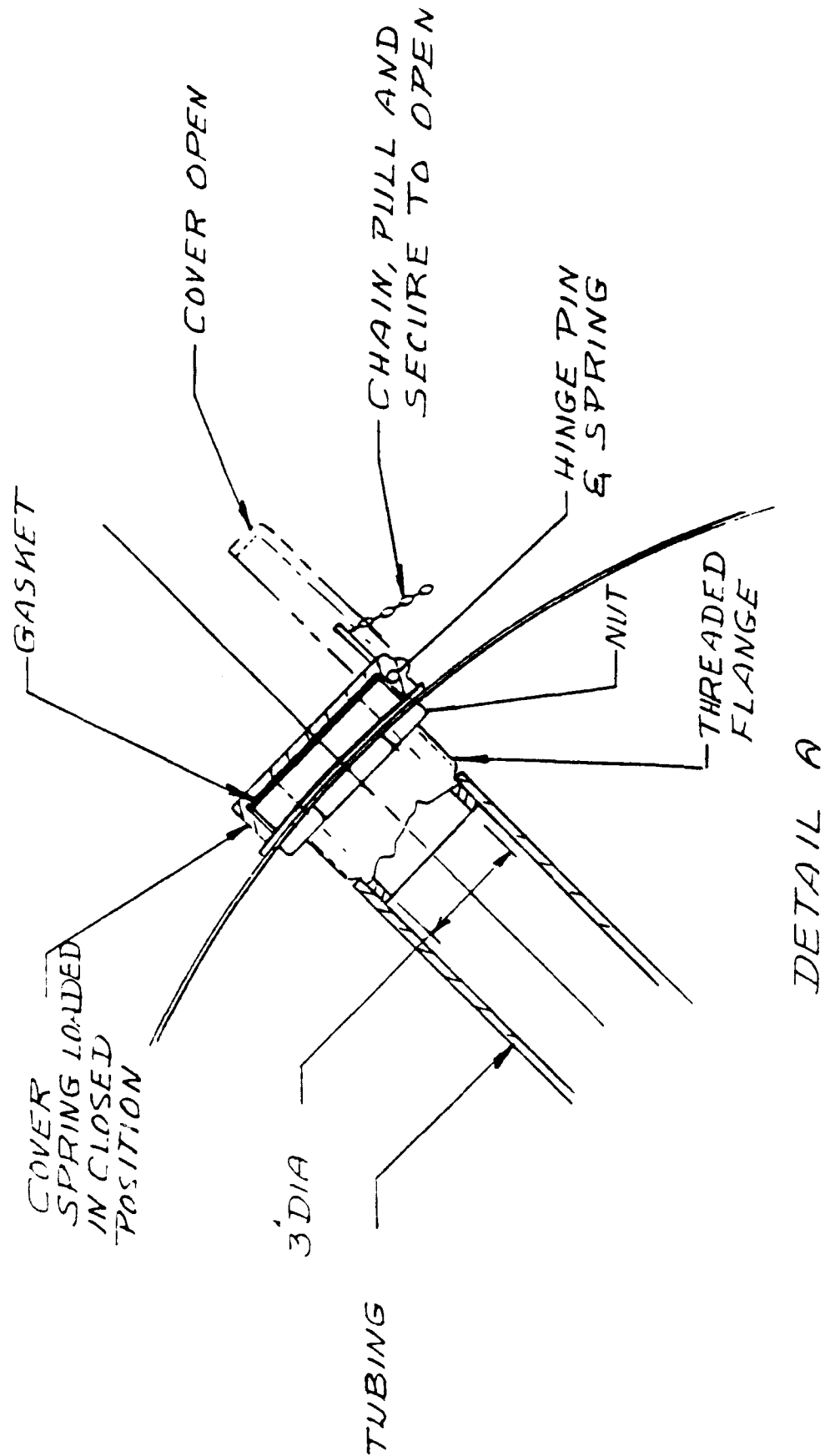


Figure 2. Detail of dome opening installation.

as shown in Fig. 1. The tube is attached to the dome at the special opening corresponding to the selected angle. The telescoping tube is adjustable in order to allow operating the instrument at different elevations angles. The required viewing angles are as follows:

Zenith: This scanning angle can be set up by positioning the pointing mirror at 45° from the horizontal position looking up, and turning the dome 180° so that the return signal is incident on the pointing mirror without obscuration by the dome.

15° From Zenith: This lidar pointing angle is set up by positioning the pointing mirror at an angle of 52.5° from horizontal position, and rotating the dome back to 0° . When the angle is set, the telescoping tube can be adjusted.

30° From Zenith: This angle can be set by positioning the pointing mirror at an angle of 60° from horizontal position and the dome at 0° . After the angle is set, the telescoping tube can be adjusted to this new position.

45° From Zenith: This angle can be set up by positioning the pointing mirror at an angle of 67.5° from horizontal position, and keeping the dome at 0° .

A study was performed to verify that at all these angles the primary mirror is completely filled and the receiver pointing mirror is not obscured.

In order to allow the lidar system to scan the above mentioned angles, a total of four small openings must be cut on the surface of the dome. The four openings would be covered by a cup that has been designed to be normally closed. When an opening is used, the cover could be opened by pulling a small chain from outside the dome. After the experiment session is terminated, releasing the chain would close the cover.

This preliminary design demonstrates that the ABLE lidar system could be installed and operated in the AFGL telescope dome. Minimal modifications to the dome are required. Lidar measurements could be made at four chosen elevation angles and any azimuth angle.

3. TRANSPORTABLE SHELTER FOR REMOTE SITE LIDAR MEASUREMENTS

To enable the ABLE lidar system to be set up at various remote sites a preliminary design of a transportable shelter was developed. Fig. 3 is the shelter front view, and Fig. 4 is the top view of the shelter roof showing the lidar transmit and receive ports.

The building floor design is square with dimensions of 16 x 16 ft and measures 8 ft in height. The roof is supported by five trusses 16 ft long and 2" high. The walls are composed of 14 panels each measuring 4 x 8 ft. Each panel is fabricated as a frame of galvanized studs covered by a sheet of galvanized steel 0.05" thick.

The eight panels that are necessary to cover the roof are: 9.5 ft long x 4 ft wide, and built with a frame of galvanized studs covered by a 0.05" thick sheet of galvanized steel. Two roof panels are equipped with an opening 38 x 45" covered by a removable cap. The purpose of the two openings is to create a window for the laser transmit beam and the receiver return beam to go through without obscuration.

In order to point at the sky from inside the shelter, the ABLE gondola has to be oriented with its front toward the side of the shelter closest to the roof openings. This arrangement eliminates all the inconveniences of optical realignments and electrical connections of the ground support equipment required for experiments conducted with the payload being moved outside the building.

The shelter design has a front door 7 ft high x 10 ft wide, which is large enough to allow the gondola in and out of the building. Galvanized sheet covers all the external surfaces, including the overhang and the front and back trusses. The floor is covered by eight plywood panels 4 ft x 8 ft x 3/4 in. thick that have 2 x 4 in stud backing. The studs overlap the plywood so that adjacent panels can be bolted on the same stud.

All 14 panels of the peripheral walls are modular in that they are bolted to each other and held at the bottom by a channel which is fastened to the floor. At the top another channel holds the panels together. On top of the channel a transition piece allows one to bolt the roof panels to the wall panels. The peak of the roof would have a capping piece to cover the upper end of the panels. The four corners would each have a post formed from galvanized steel sheet metal.

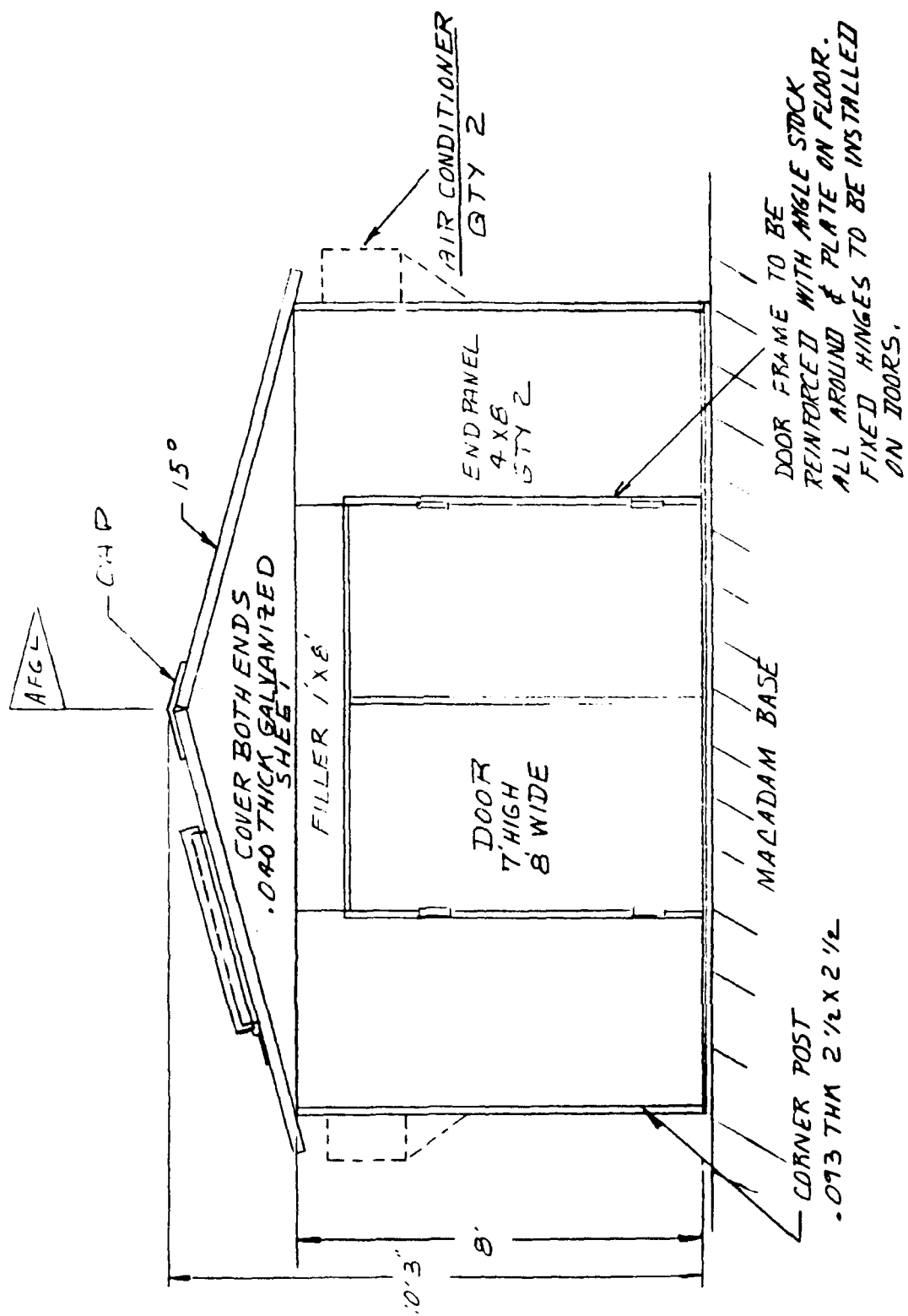


Figure 3. Transportable shelter, front view.

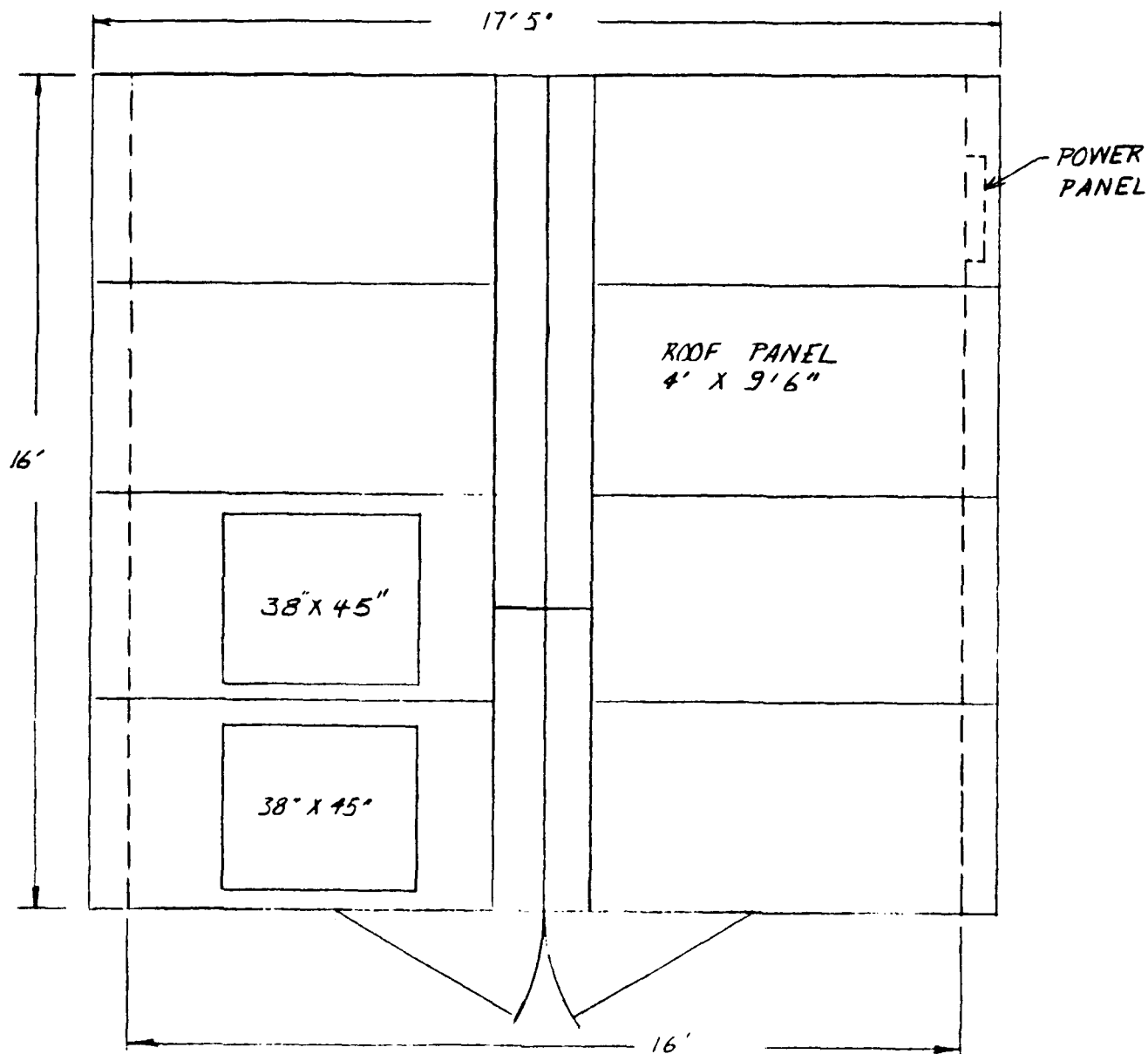


Figure 4. Transportable shelter, top view.

The five trusses have been designed to withstand a wind load of 20 lb/ft² on the roof. Foil-faced insulation one inch thick will cover the walls and the roof. The insulation and the facing would contribute to keeping the inside of the shelter cool, so that two small air conditioners could maintain reasonable working conditions. This is important because the door must be kept closed as much of the time as possible to protect optical components from dust.

The floor would be painted to keep dust to a minimum. A small ramp would be provided at the entrance to assist in moving cargo, including the gondola, in and out of the shelter. It would be similar in construction to the floor.

4. SOUTH ATLANTIC BACKSCATTER LIDAR EXPERIMENT, SABLE 89

4.1 Experiment Description

SABLE 89 was a GL measurement program which made a set of coordinated lidar measurements from Ascension Island in the South Atlantic Ocean. The lidars deployed to Ascension Island for the program were the following:

1. The Royal Aircraft Establishment (RAE) airborne CO₂ Doppler lidar. This lidar was installed in a Canberra aircraft, and its mission was to acquire 10.6 μm aerosol backscatter at altitudes up to 50 000 feet.
2. The AFGL coherent CO₂ lidar van. The measurement objective of this system was to acquire altitude-resolved 10.6 μm aerosol backscatter data.
3. The ABLE groundbased lidar system. The measurement objective of this lidar was to acquire 532 nm and 355 nm altitude-resolved backscatter from aerosols and clouds.

4.2 Preparations

The lidar system was refurbished prior to field deployment. This included refurbishment and realignment of the Nd:YAG laser. To transfer the acquired lidar data to the AFGL MicroVax computer, a parallel data interface connecting the ABLE CAMAC system with the computer was designed, fabricated, and tested. This interface consisted of hardware electronics, VAX software, and CAMAC control software development.

The ABLE system was refurbished and aligned at Visidyne, Inc. and then it was shipped to the GL high bay at Hanscom AFB, MA for testing. Upon completion of the predeployment testing, the payload was packed for shipment to Ascension Island. There the ABLE lidar system was set up at the MET Hangar (Fig. 5). The measurement configuration of the ABLE groundbased lidar system is shown in Fig. 6.

4.3 SABLE Field Log

18 June 1989, Sunday

Left Boston 1255 EDT

Arrived at Melbourne 1715 EDT

AF Bus to Patrick AFB BOQ and Overnight



Figure 5. MET hangar, field site on Ascension Island.



Figure 6. ABLE lidar, measurement configuration, Ascension Island.

19 June 1989, Monday

Left BOQ at 1100 EDT
Take Off for Antigua 1530 EDT
Arrived Antigua 1830 EDT
Dinner and Snack Bar
Took off for Ascension Island 2057 EDT
Overnight on Aircraft

20 June 1989, Tuesday

Arrived AI at 0430 EDT or 0830 Zulu
Went to assigned rooms (grim!)
No choice of rooms till Monday at earliest
Located four equipment boxes, VAX, Tektronics, four chemical boxes, and
payload
Noted payload strapping for air shipment
Located trailer, toured Long Beach, Georgetown, and trailer site. Ended
at Volcano Club.

21 June 1989, Wednesday

Boxes to MET hangar
Called Visidyne
Arranged boxes in hangar
Payload brought from TMO shed to hangar by forklift (payload mounted on skid and
C141 pallet)
Unpacked payload and inspected exterior

22 June 1989 - Thursday

Forklift sent by TMO (6K) was too small to lift payload off of pallet.
Heavy forklift came and lifted payload off of pallet/skid and set it
on hangar floor. Skid to Sea Land container. Inspected laser, CAMAC, and
payload set up for external power test. Found four nuts and a lock
washer loose in one of the laser 28 VDC power supplies.
Powered up payload
Booted computer (11/23) and ran SABLE

Quick system check, OK

He-Ne laser was slow (~ 30 sec) starting

Cooling system was observed for leaks

Set up calorimeter on beam

Set up standard lamp mount on payload

Preliminary plans were developed for an exterior ramp to provide zenith laser firing capability.

23 June 1989, Friday

Found that LEM \pm 15 volt power supply was not operational; + 15 volt was shorted to ground when LEM was connected to payload. Removed unused + 28 volt circuit in the LEM connector to fix.

24 June 1989, Saturday

Calibrated horizontal laser beam by comparing LEM and calorimetric data.

Preliminary calibration of receiver detectors. Rolled out for first lidar test after sunset and operated lidar for approximately 15 minutes. Shut down when no data were observed.

25 June 1989, Sunday

Arrived at Met hangar at 0515 and rolled out for lidar test. Heavy, low-level cumulus clouds and high cirrus. Operated lidar no backscatter data observed. Concluded that the telescope must be apertured down to reduce backscatter. Installed 50 cm² aperture for evening mission. Recorded background levels for approximately one hour after sunrise. This was not a typical morning because sun was obscured by dense cumulus clouds.

Midday off.

Returned to Met hangar at 0700 for lidar test with reduced aperture. No backscatter data observed. Check timing and found data were not in proper sync with respect to CAMAC timing generator.

26 June 1989, Monday

Arrive at Met hangar at 0800 and performed timing test. Opened laser power supply chamber and found that laser switch was set for 10 pps. Internal rather than for external trigger pulse. Performed full receiver detector

calibration. Returned to Met hangar at 1900. Lidar data recorded by VAX and displayed in real time. All detectors operational.

27 June 1989, Tuesday

Arrive at Met hangar at 0500. Operated lidar for 30 minutes prior to sunrise. Observed both low level clouds and high altitude cirrus. Used 1/2 telescope aperture.

Opened laser chamber and inspected laser, TIR prism had deteriorated further. Inspected laser pointing mirror and found that for zenith pointing, laser was hitting upper mirror frame. Decided to forego zenith geometry in favor of 30 degree pointing. Cleaned laser pointing mirror with lens tissue and distilled water. Reagent grade alcohol was contaminated by USAF when it was transferred to a metal container for air shipment. Attempted to calibrate the zenith and 30 degrees beams using hand-held calorimeter. Found that UV output was very low. Previous calibration of LEM was probably not correct. Tuned green and UV xtals for max output of UV (~ 10 mJ/pulse). Changed payload rollout configuration to permit the use of 30 degree beam.

Returned to Met hangar at 1900. Sky was the most cloud-free since arrival.

Some low cumulus and high cirrus. Ran for approximately one hour using 1/2 telescope aperture. Much less cloud backscatter was observed than during AM measurements. At end of data acquisition period, some problems occurred.

1. VAX hard disk (data) became hung up and data could not be accessed.
2. DC power supply used to power the receiver electronics failed. Main fuse had been blown.
3. DEC 11/23 computer suddenly lost power momentarily.

6/28/89 morning data were canceled to allow time to recover data from VAX and to prepare it to acquire data.

28 June 1989, Wednesday

J.W. was able to fix the rental (Visidyne) VAX by switching ports on the controller board. J.W. was able to recover and tape backup the previous

evening's data. Tested VAX/ABLE link and had Timeout Error. Replaced interface electronics with backup - transfer IK with ABLET2. Reconnected prototype and transfer OK.

Problem Status:

1. VAX OK (see below).
2. DC Power Supply - replaced with spare.
3. DEC 11/23 Power - Found faulty power strip connector and switched connectors.

Visited Canberra aircraft and watched tape of single engine landing, long take-off, and RAE tape of SABLE 88.

At Met hangar at 1900. Set up payload to probe at 30° from zenith and 290° (magnetic) azimuth. Varied aperture sizes from 3 cm^2 to $1/2$ aperture ($1897/2 = 948.5 \text{ cm}^2$). Ran for $3 \times 90 \times 100$ major frame/integration.

Lidar data obtained on all detectors.

29 June 1989, Thursday

At Met hangar at 0500. Made another run with varying aperture sizes from 3 cm^2 to full aperture (1897 cm^2). Ran pulse-counting detectors to 0650 with a 3 cm^2 aperture. No excessive background observed. Brush chart recorder failed after 180 integrated frames had been recorded. Video recorder tape transport failed, but was later repaired.

30 June 1989, Friday

0600 at Met hangar.

0600 laser on.

Ran three files of data against cloud. Shut down laser at 0703 due to incoming RAF Tristar aircraft. Rest of day off.

1 July 1989, Saturday

0630 at Met hangar.

Ran two data sets with reduced aperture in daylight until 0704. Assembled and dc-tested the 1064 nm detector. Performed a time zero calibration using scattered laser light inside the Met hangar. Determined that a phase correction factor is required for the current mode detectors.

Found that an improperly mated connector caused the LEM data not to be included in the major frame data recorded to date.

To Met hangar at 1800 and set up for laser calibration. Tuned green for maximum, UV for maximum, and green for UV max. 7/3/89 aircraft mission is to be major data acquisition; thus no data will be acquired until 7/3/89.

2 July 1989, Sunday

Off day.

Island tour with Gino (am).

Pan Am Beach for swimming and fishing (pm).

3 July 1989, Monday

0800 to Met hangar.

Developed rental VAX failure history with J. Wolfenden

Reviewed R. Wattson software with S. Rafuse

Tested noise and electronics of 1064 nm detector

Updated log and calibration data.

Realigned payload azimuth from 290 degrees to 315 degrees so as to be parallel with runway.

LEM data has a +15 volt common mode voltage on the data lines. Data cannot be recorded digitally.

Left hangar at 1600 and returned at 1800 to prepare for all-up dark run.

Aircraft takeoff at 1933. Laser turned on at 1934. Data acquired continuously with various aperture sizes until aircraft landing at 2115.

4 July 1989, Tuesday

0800 at Met hangar. Packed MicroVax for shipment. Updated log and data.

Afternoon off.

5 July 1989, Wednesday

0800 at Met hangar. Calibrated laser and receiver. Base power to be off from 1000 to 1800. Ran cals using auxiliary generator power. Did not test VAX link.

Returned to Met hangar at 1800 and turned on lidar when aircraft took off.

Ran using various apertures and ND filter until approximately 2030 when the laser abruptly shut down.

6 July 1989, Thursday

Arrived at MET hangar at 0800. Inspected laser and found nothing obviously wrong with laser. Calibrated LEM using the calorimeter and tuned the SHG and THG crystals for maximum UV output. Left Met hangar at approximately 1200 and returned at 1800. Turned on lidar when aircraft was airborne and recorded data until 2040. Laser abruptly shut down once during the measurements. Excellent backscatter from high cirrus clouds was observed.

7 July 1989, Friday

No aircraft mission. Lidar on at 1941 hr. and acquired data with a 100 cm² aperture at 2000 hrs. Laser shut down. Turned on at 2030 hr. and shut down again. Determined that the laser power supply over-temperature interlock had tripped because power supply chamber fan was not running. Inserted a fan in the chamber to correct problem.

8 Jul 1989, Saturday

Turned on lidar at 2019 and acquired data until 2025.

9 July 1989, Sunday

Configured lidar for horizontal firing. Set up for 84.5° azimuth and 5.5° elevation above the horizontal plane. Turned on lidar at 1921 hrs. and acquired data using various apertures until 2056 hrs.

10 July 1989, Monday

Packed payload and boxes.

11 July 1989, Tuesday

Off day.

12 July 1989, Wednesday

Left Ascension Island on C-141 MAC flight and arrived at Patrick AFB.

Drove to Orlando for Delta flight to Boston.

4.4 Summary and Results

The ABLE lidar data were transferred to the GL MicroVax computer where the backscatter data were averaged and recorded on hard disk. The data were archived onto TK 50 cartridge tapes. A record of the lidar data recorded is in Tables 1 through 8.

During the SABLE 89 measurements program, the ABLE groundbased lidar system acquired many hours of aerosol and cloud backscatter data. Figs. 7-9 are typical examples of the two-wavelength backscatter data obtained. It is recommended that these data be analyzed and that additional measurements be performed.

Table 1

SABLE 89 Data
30 June 1989

Time (Z)	Aperture (cm ²)	Laser Energy Monitor		
		1064 nm	532 nm	355 nm
0633	3		3.34	2.37
0636			3.22	2.50
0640			3.13	2.66
0644	End 90			
0645			3.14	2.69
0649			3.16	2.69
0650			3.22	2.72
0653		6.67	3.24	2.65
0655		6.70	3.24	2.68
	LEM Reference	1.00	0.41	0.38
	End 90			
0710		6.67	3.17	2.55
		6.54	3.03	2.72
	LEM Reference	0.99	0.41	0.38
	End 48			

Table 2
SABLE 89 Data
1 July 1989

		Laser Energy Monitor		
Time (Z)	Aperture (cm ²)	1064 nm	532 nm	355 nm
	LEM Reference	1.00	0.41	0.38
0632	6		3.25	2.33
0635	12		3.14	2.58
0638	25		3.05	2.77
0641	50		3.06	2.78
0643	End 90			
0644	100	6.82	3.12	2.78
	W. Dat			
0647	950		3.06	2.80
0653	3		3.12	2.78
0654	3			
	End 90			
0655	3	6.85	3.21	2.79
0704	End 61			

Table 3

SABLE 89 Data
3 July 1989
Mostly Clear Sky

Time (Z)	Aperture (cm ²)	Laser Energy Monitor		
		1064 nm	532 nm	355 nm
	LEM Reference	0.99	0.40	0.13
1933	Aircraft Liftoff			
1934	950	6.82	2.91	2.01
1937	950	6.13	3.19	1.90
1943	950	6.04	3.03	2.19
1945	950	6.12	3.11	2.21
1952	950	6.15	3.18	2.22
	End 42/2			
1958	50	6.26	3.18	2.18
	50	6.32	3.26	2.17
2006	50	6.25	3.23	2.17
	End 90/3			
2008	25			
2013	12.5	6.39	3.15	2.17
2020	50	6.37	3.11	2.17
	End 90/4			
2030				
2031	100			
2032	100	6.21	2.94	2.34
2035	100	6.18	2.85	2.35
	100	6.17	2.81	2.36
	End 90/5			

2043	950			
2049	100			
2054		6.04	2.63	2.41
	End 90/6			
2053	475	6.00	2.65	2.41
2103	475	6.02	2.51	2.41
2105	475	6.02	2.55	2.41
	End 90/7			
	LEM Reference	0.98	0.40	0.37
2115	Aircraft on Ground			

Table 4

SABLE 89 Data
5 July 1989

Time (Z)	Aperture (cm ²)	Laser Energy Monitor		
		1064 nm	532 nm	355 nm
1925	Aircraft Liftoff			
1924	50	7.30	2.52	2.11
1929	50	6.54	2.35	2.37
1938	50	6.74	2.35	2.37
	End 90/1			
1938	M.DAT			
1941	100	6.69	2.36	2.42
	100	6.90	2.45	2.44
	100	6.88	2.51	2.39
1949	90/2			
	N.DAT			
	100	6.81	2.44	2.32
2000	End 90/3			
2002	50	6.91	2.46	2.32
	O.DAT			
	25			
	6			
	25			
2012	100	6.95	2.33	2.38
	End 90/4			
2014	P.DAT			
	100	6.76	2.35	2.39
	100	6.81	2.28	2.36
	End 90/5			

2026	100			
	50			
2028	25			
	12			
	6			
2029	3			
	ND1.0			
	ND2.0			
	ND3.0			
	Laser Shut Down Due to Power Supply Over-Temperature			

Table 5

SABLE 89 Data
6 July 1989
Good Cirrus Data

Time (Z)	Aperture (cm ²)	Laser Energy Monitor		
		1064 nm	532 nm	355 nm
1915	Aircraft Takeoff			
1921	50	7.70	2.20	2.27
	50	6.20	2.37	2.26
1934	50	6.38	2.34	2.49
	A.DAT			
	50	6.56	2.39	2.49
1941	50	6.55	2.41	2.44
1944	50	6.66	2.44	2.47
1947	100	6.52	2.48	2.51
1950	Laser Shut Down			
2002	100	6.99	2.33	2.38
	B.DAT			
	100	6.29	2.36	2.43
2012	100	6.48	2.22	2.40
	100	6.54	2.20	2.35
2015	Laser Shut Down			
2019	100			
2022	100	6.40	2.27	2.41
2025	100	6.30	2.20	2.33
	C.DAT			
2031	950	6.46	2.10	2.27
2035	950	6.51	2.20	2.25
2040	950	6.40	2.12	2.20

Table 6

SABLE 89 Data
7 July 1989

		Laser Energy Monitor		
<u>Time (Z)</u>	<u>Aperture (cm²)</u>	<u>1064 nm</u>	<u>532 nm</u>	<u>355 nm</u>
	No Aircraft			
1941	Shutter In			
1943	100	6.80	2.22	2.31
	100	6.16	2.39	2.37
	100	6.15	2.35	2.39
	End 90/1			
1955	E.DAT			
	100	6.49	2.38	2.38
	100	6.46	2.42	2.39
	Laser Shut Down			
2031	100	6.12	2.10	2.23
	100	6.12	2.06	2.20

Table 7

SABLE 89 Data
8 July 1989

<u>Time (Z)</u>	<u>Aperture (cm²)</u>	Laser Energy Monitor		
		<u>1064 nm</u>	<u>532 nm</u>	<u>355 nm</u>
1919	100			
1920	100	6.50	2.36	2.20
		6.07	2.29	2.29
1925	Aircraft Takeoff			
	G.DAT			
1932	100	6.17	2.33	2.35
1942	100	6.40	2.29	2.34
1946	950			
1949	950	6.30	2.30	2.34
1952	950			
1952	950	6.31	2.26	2.30
1959	950	6.27	2.23	2.30
2010	950	6.32	2.15	2.25
2012	100			
2014	100	6.22	2.14	2.22
	H.DAT			
2025	100	6.31	2.06	2.07
2027	100	6.23	2.02	2.02
2040	Laser Off			

Table 8

SABLE 89 Data
9 July 1989

Elevation - 5.5 Deg. Above Horizontal
Azimuth 84.5 Deg.
Light Rain

Time (Z)	Aperture (cm ²)	Laser Energy Monitor		
		1064 nm	532 nm	355 nm
1921	100	6.91	2.08	1.88
	100	6.11	2.10	2.18
1935	25	6.07	2.12	2.17
	25	6.11	2.19	2.24
	J.DAT			
	25	6.30	2.13	2.20
1952	25	6.32	2.15	2.18
	25	6.42	2.09	2.11
2011	25	6.44	1.95	2.00
	K.DAT			
2029	25	6.21	1.84	1.90
2042	950	6.18	1.75	1.77
2044	25	6.15	1.77	1.78
2046	25	6.11	1.74	1.76
	L.DAT			
	M.DAT			
		6.04	1.73	1.60
2056	Laser Off			
	LEM Reference	1.00	0.38	
Conclusion of SABLE 90 Data Acquisition				

30 JUN 1989 - 0644

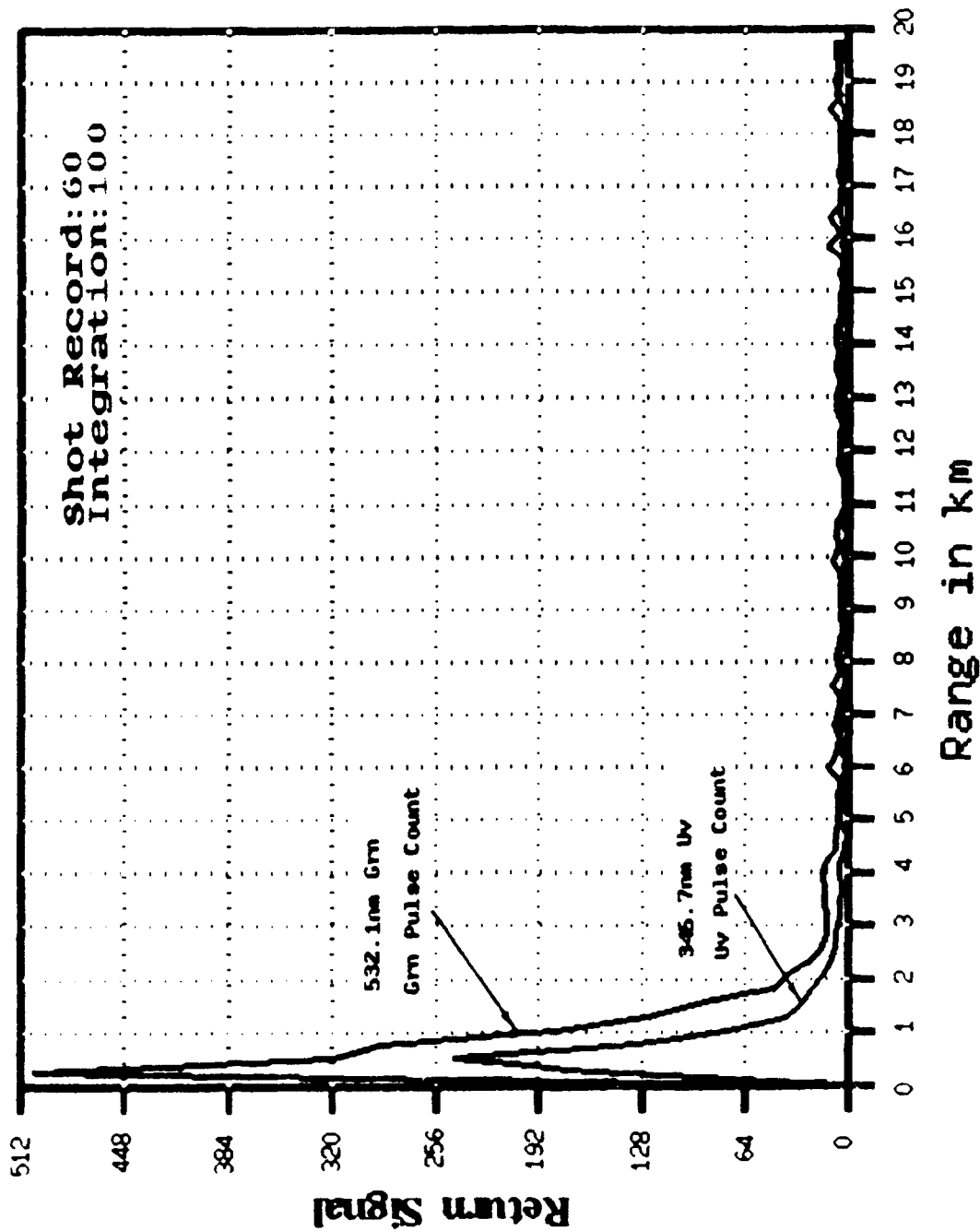


Figure 7. SABLE 89 backscatter data, clear sky.

1 JUL 1989 - 0630

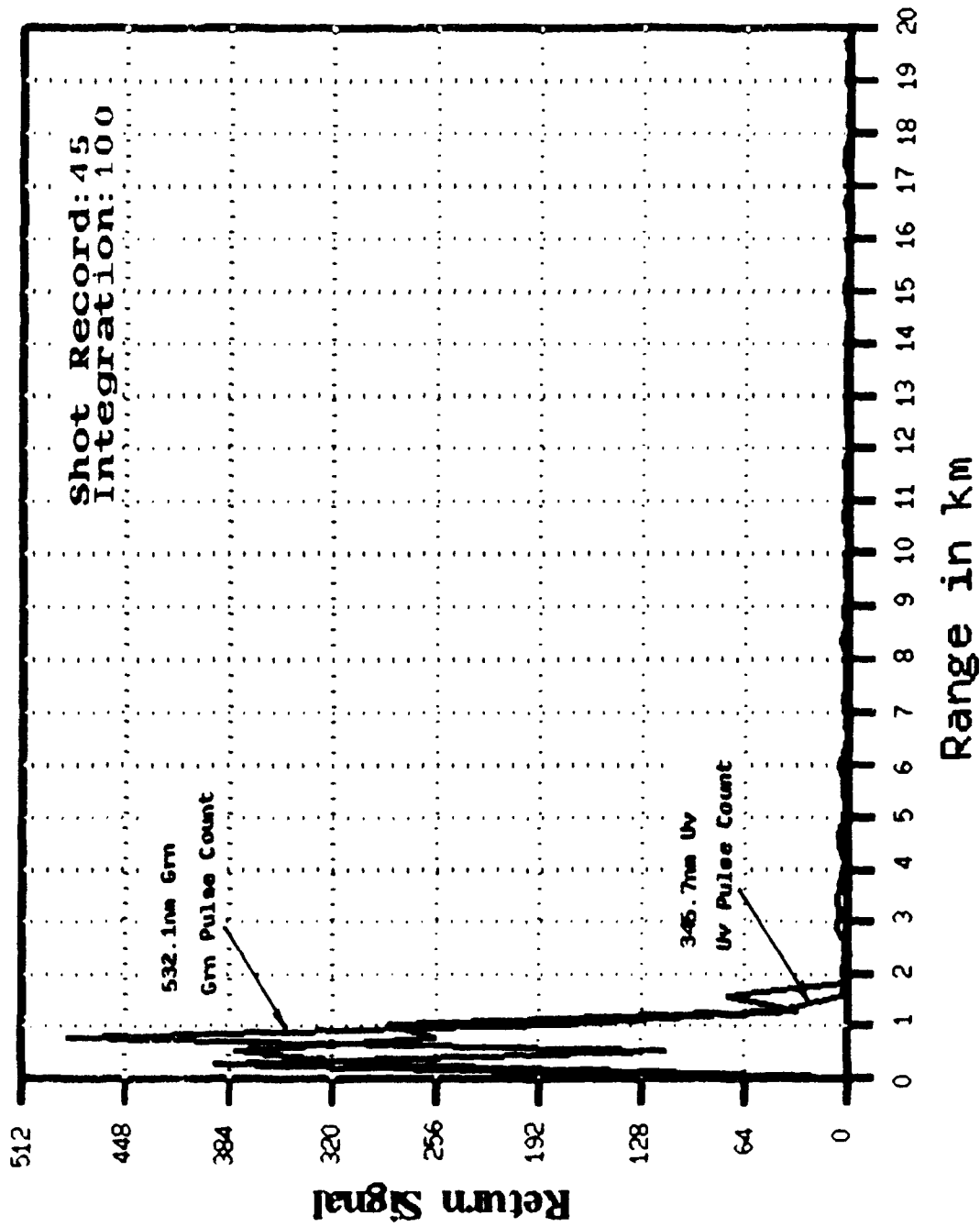


Figure 8. SABLE 89 backscatter data, low altitude clouds.

6 JUL 1989 - 2031

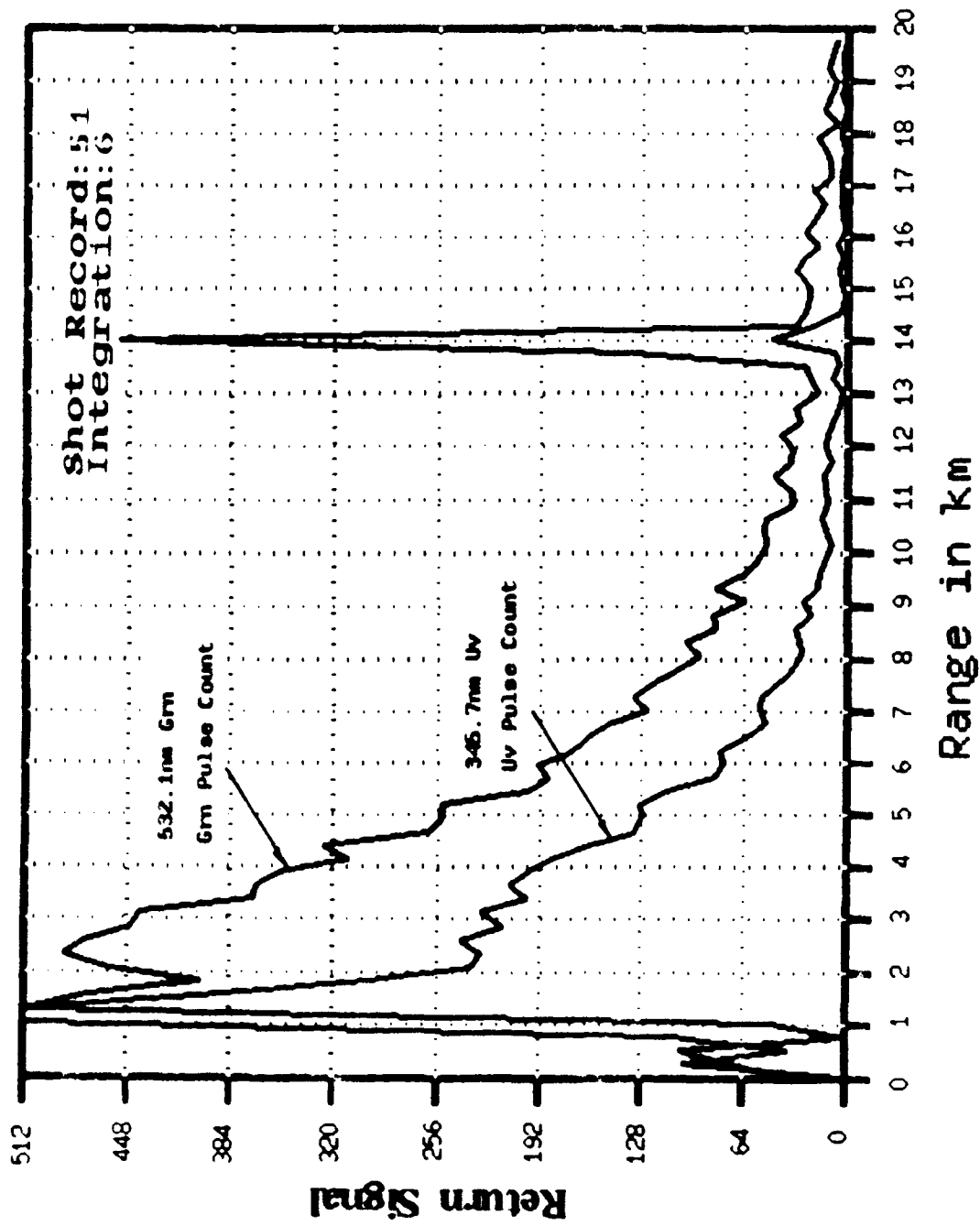


Figure 9. SABLE 89 backscatter data, high cirrus clouds.

5. GREATER ATLANTIC BACKSCATTER LIDAR EXPERIMENT, GABLE 90

5.1 Experiment Description

GABLE 90 was a GL measurement program similar to SABLE 90 but performed at a different field site. During the period of 5 August 1990 to 25 August 1990, the ABLE system was deployed to Terciera, Azores, Portugal to make groundbased lidar measurements. The ABLE system was configured to acquire aerosol and cloud backscatter data at 532 nm and 355 nm. The lidar was capable of operation with elevation angles at zenith and 30 degrees off zenith.

5.2 Preparation

Prior to deployment the lidar system was refurbished and aligned, and the receiver and transmitter were calibrated. On 3 July 1990 the ABLE system was shipped to the GL high bay where additional system calibration was performed. An objective of this measurement effort was to have the ABLE lidar system control function be done using a GFE Northgate PC-386 computer. This would have replaced the existing LSI 11/23 computer used for earlier balloonborne operations of the ABLE system. A software conversion was required to implement the replacement. A hard disk head crash in the PC-386 computer during high bay testing terminated this effort. The disk was replaced, and the computer was shipped out, but it did not arrive at the field site in time.

On July 1990 the ABLE system was palletized and sealed for shipment. The payload and three boxes of equipment were transported to McGuire AFB, NJ for MAC shipment to Lejes AFB, Terciera, Azores. On 4 August 1990 GABLE 90 personnel departed from Boston to McGuire AFB for a C141 MAC flight to Lejes AFB.

The field site at Cinco Pico on Terciera is shown in Fig. 10, and Fig. 11 shows the payload on the deck prepared for measurements.



Figure 10. ABLE lidar (center) and GL CO₂ lidar van (right) at Cinco Pico site, Terciera, Azores.

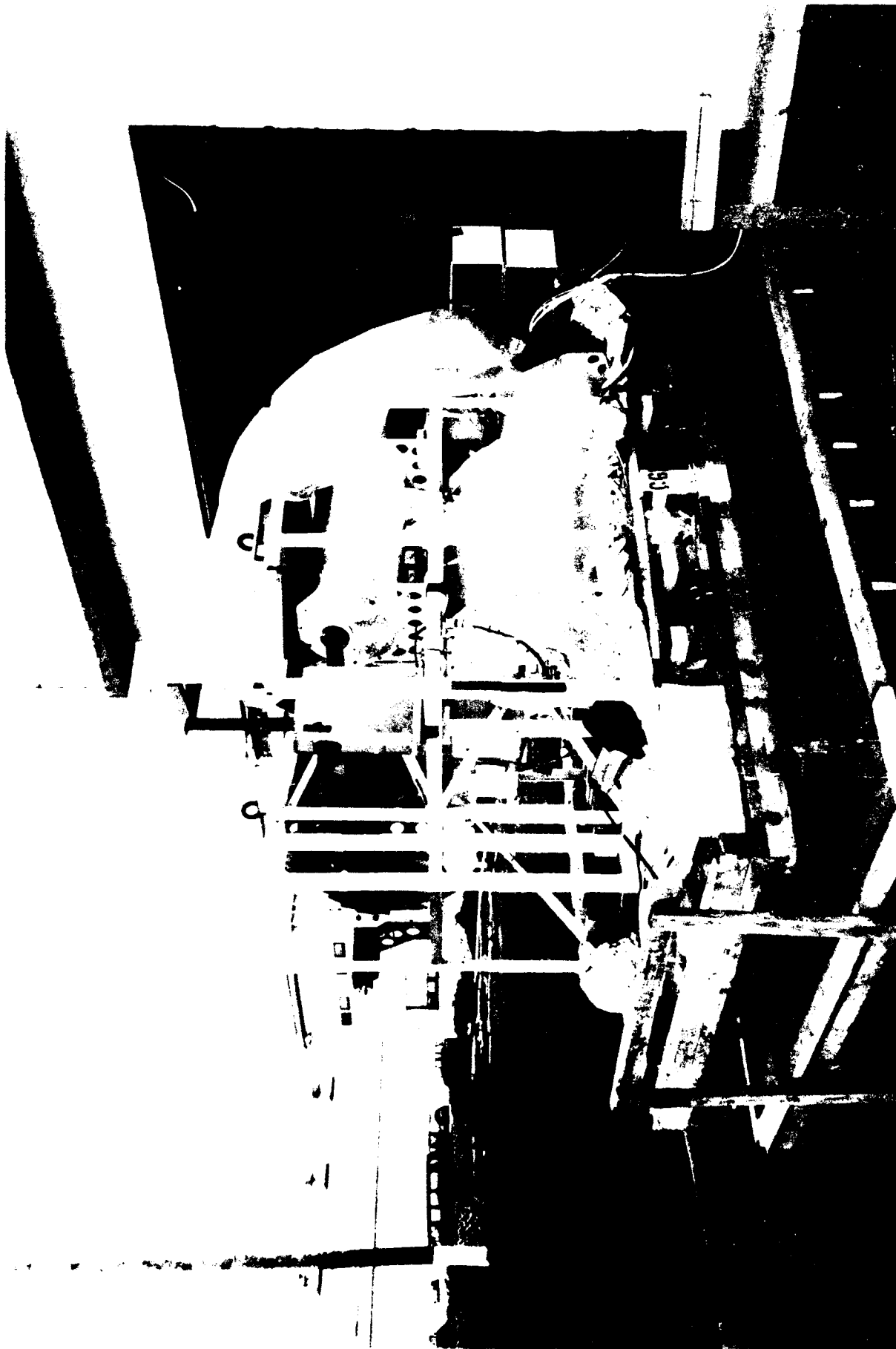


Figure 11. ABLE lidar, measurement configuration, Cinco Pico site, Terciera, Azores.

5.3 GABLE Field Log

6 August 1990

The ABLE lidar system was transported to and set up at the transmitter site at Cinco Pico on Terciera. Also installed at the site was the GL CO₂ lidar van.

The ABLE system and the three crates were unpacked and the system electrically checked out.

7 August 1990

Weather - Heavy Low Altitude Clouds

The optical alignment of the laser was checked and the laser baffles, which had been removed for shipping, were installed. The receiver telescope was inspected, and a broken cable was fixed.

Since there was no forklift available, the ABLE payload had to remain on the shipping pallet. To enable the payload to be moved out of the transmitter building to make upward viewing lidar measurements, a local contractor fabricated a temporary deck and mounted wheels on the pallet.

8 August 1990

Weather - Rain, A Tropical Storm Passed Over the Island

The mounting of the pallet wheels was completed. The Laser Energy Monitor calibration was performed on the 1064 nm monitor and rescaled to reduce the measured signal voltage by a factor of two.

9 August 1990

Weather - Rain, Wind and Low Clouds

A lidar receiver calibration of both the pulse counting and current detectors was performed.

10 August 1990

The PCM data interface between the ABLE data system and the VAX was checked out, and housekeeping data were recorded.

11 August 1990

Off Day.

12 August 1990

The ABLE system was rolled out onto the deck at 1900 hours and prepared for measurements. The system was turned on at 2205 hours. Shortly after turn-on it started to rain. The system was covered and brought back into the building, and no more measurements were attempted in the evening.

13 August 1990

Weather - Clear to Partly Cloudy with Scattered Rain

Lidar Data

		LEM Data	
<u>GMT</u>	Aperture cm ²	<u>532 nm</u>	<u>355 nm</u>
2113	4	0.43	0.38
2119	4		
2121	4	0.42	0.37
2129	4	1.14	2.44
2132	4	1.14	2.43
2145	4	1.14	2.21
2146	1		

14 August 1990

Weather - Clear with Partly Cloudy

Lidar Data

		LEM Data	
GMT	Aperture cm ²	532 nm	355 nm
2210	4	0.42	0.38
2214	Laser- On	1.14	1.93
2222	4	0.78	2.02
2229	4	0.77	1.99
2230	1	0.75	1.99
2236	1	1.075	1.68
2239	1	1.068	1.95
2241	1	1.053	1.91
2245	1	0.74	1.86
2255	4	1.016	1.76
2304	9	0.966	1.69
2308	Laser-Off	0.414	0.34
2334	4	0.356	1.02
2342	4	0.960	1.37
2343	9	0.943	1.31
2345	16	0.925	1.20
2354	16	0.906	1.19
2358	16	0.906	1.22
0011	Laser-Off	0.413	0.37

15 August 1990

Weather - Clear with High Clouds

Lidar Data

		LEM Data	
<u>GMT</u>	Aperture cm ²	<u>532 nm</u>	<u>355 nm</u>
0620	4	0.904	1.60
0633	4	0.920	1.60
0637	4	0.908	1.60
0653	4		
0655	9	0.860	1.14
0702	9	0.825	1.04
0705	9	0.813	1.22
0710	9	0.783	1.10
0718	9	0.743	1.02
0726	9	0.703	0.69
0737	9	0.688	0.61
0739	9	0.658	0.56
0741	Laser Off	0.417	0.16

16 August 1990

Weather - Partly Cloudy

A laser calibration was done, and the SHG and THG pulses were readjusted to maximize laser output pulse energy. A significant energy increase was obtained.

Lidar Data

		LEM Data	
<u>GMT</u>	Aperture cm ²	<u>532 nm</u>	<u>355 nm</u>
2149	4	0.42	0.38
2153	4	0.58	0.78
2216	9	0.56	0.67
2229	9	0.56	0.62
2240	9	0.56	0.62
2247	9	0.58	0.69
2254	9	0.58	0.72
2300	9	0.58	0.73
2319	9	0.58	0.75
2324	9	0.58	0.78
2353	Laser Off	0.41	0.378

17 August 1990

Lidar Data

		LEM Data	
<u>GMT</u>	Aperture cm ²	<u>532 nm</u>	<u>355 nm</u>
2141		0.423	0.38
2144	1	0.57	0.56
2149	4	0.57	0.61
2201	4	0.575	0.66
2207	4	0.583	0.68
2214	9	0.582	0.69
2226	9	0.582	0.71
2236	9	0.571	0.72
2242	9	0.575	0.71
2247	100	0.572	0.72
2250	25	0.561	0.72
2256	Laser Off	0.417	0.37

18 August 1990

Lidar Data

		LEM Data	
<u>GMT</u>	Aperture cm ²	<u>532 nm</u>	<u>355 nm</u>
2049	4	0.424	0.38
Laser On			
2125	1 + 1.0 ND	0.506	0.50
2128	1 + 4.0 ND	0.539	0.53
2136	1 + 4.0 ND	0.542	0.57
2142	1	0.553	0.58
2148	4	0.551	0.57
2203	4	0.541	0.58
2206	9	0.539	0.58
2215	9	0.537	0.58
2232	9	0.533	0.60
2247	9	0.527	0.60
2251	16	0.528	0.59
2255	25	0.525	0.59
2258	50	0.519	0.59

19 August 1990

Off Day.

20 August 1990

Lidar Data

		LEM Data	
GMT	Aperture cm'	532 nm	355 nm
2003		0.421	0.38
Laser On			
2029	1 + ND 2.0	0.517	0.48
2031	1 + ND 1.5	0.517	0.50
2032	1	0.519	0.51
Laser Off			
Laser On			
2041	1	0.520	0.50
2047	1		
Laser Off			
2048	1	0.526	0.52
2002	1	0.527	0.54
2116	1	0.520	0.55
2128	1	0.521	0.54
2120	4	0.520	0.54
2147	9	0.516	0.54
2201	9	0.516	0.54
2218	16	0.511	8.52
2221	100	0.501	0.49
2239	50	0.501	0.49
2249	50	0.505	0.50
Laser Off			

21 August 1990

Packed for redeployment.

22 August 1990

Packed for redeployment.

23 August 1990

MAC flight from Lajes Field to McQuire AFB.

24 August 1990

Commercial flight from Philadelphia to Boston.

5.4 Summary and Conclusions

Over the period of the GABLE measurements, the ABLE lidar exhibited a loss in output pulse energy at the two measurement wavelengths. This energy loss did not degrade the lidar measurement capability because the receiver aperture, which was stopped down for the measurement, was opened up to compensate for the energy loss. A post-mission examination of the laser indicated that the probable cause of the loss was the reduced light output from the laser oscillator cavity flash lamp. The lamp has since been replaced.

The ABLE system acquired an excellent set of backscatter data during the GABLE 90 measurement program. Typical examples of the data are shown in Figs. 12-15. It is recommended that a complete analysis of these data be done.

12 AUG 1990 - 2208

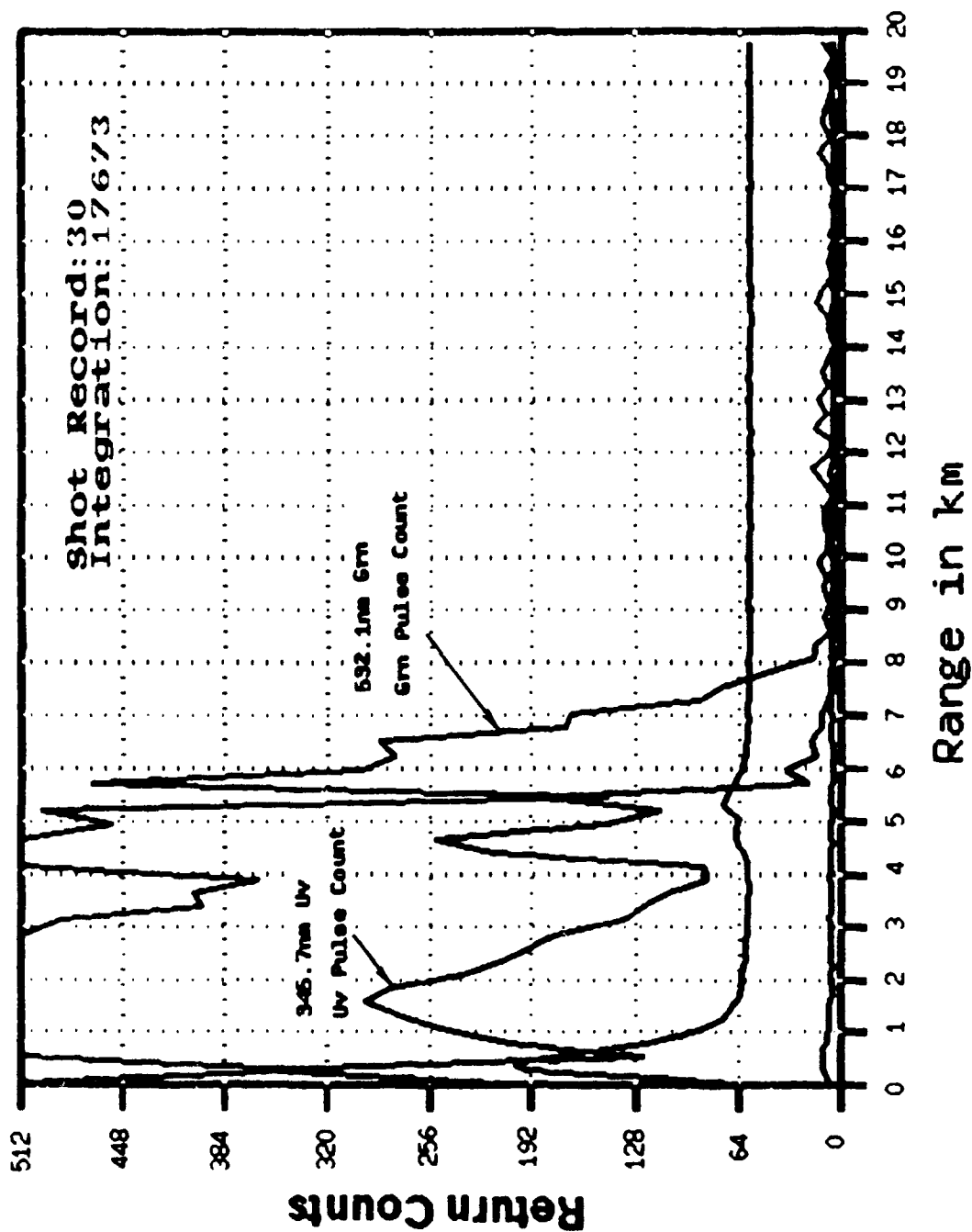


Figure 12. GABLE 90 backscatter data, multiple cloud layers.

15 AUG 1990 - 0620

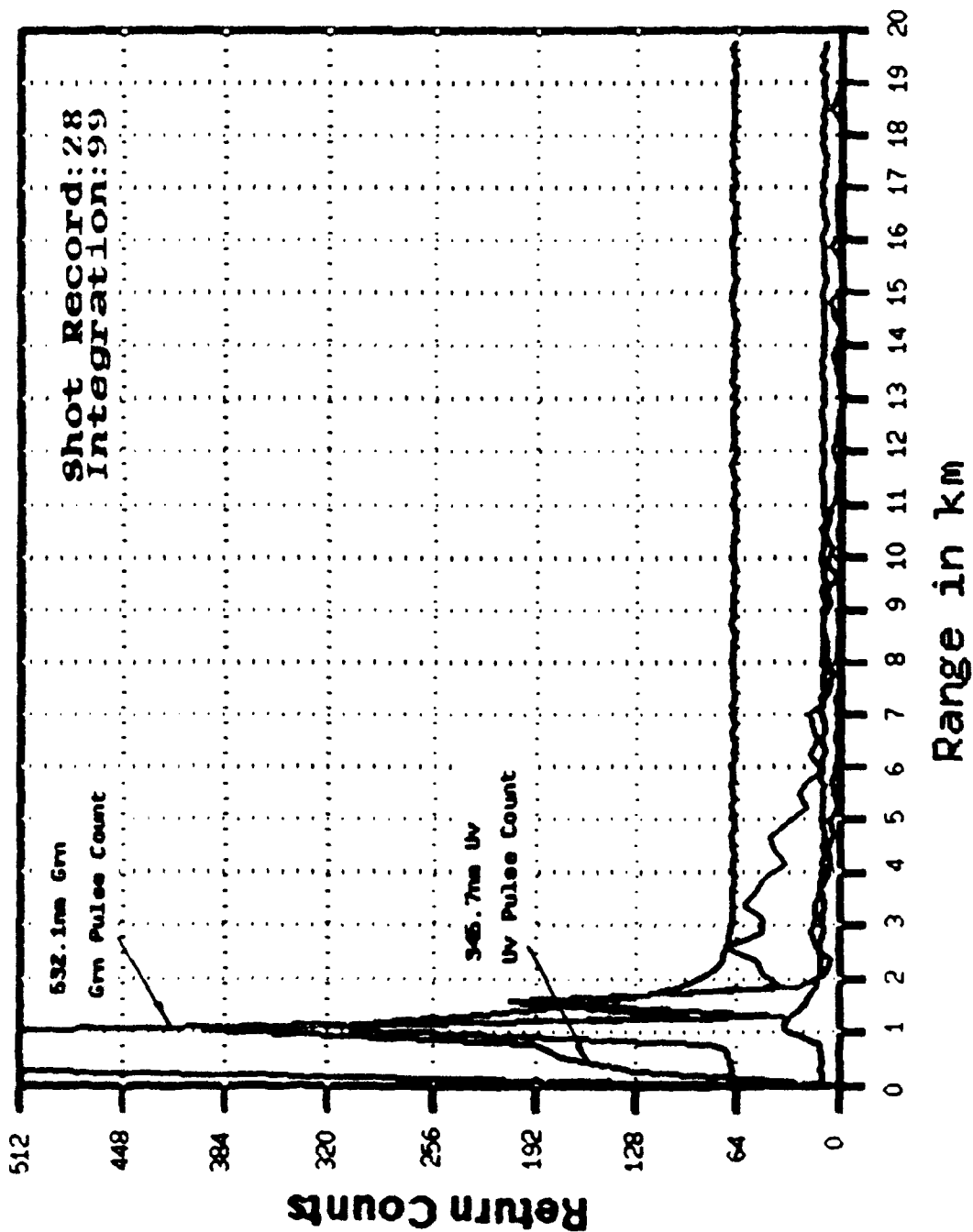


Figure 13. GABLE 90 backscatter data, dense low-level clouds.

17 AUG 1990 - 2214

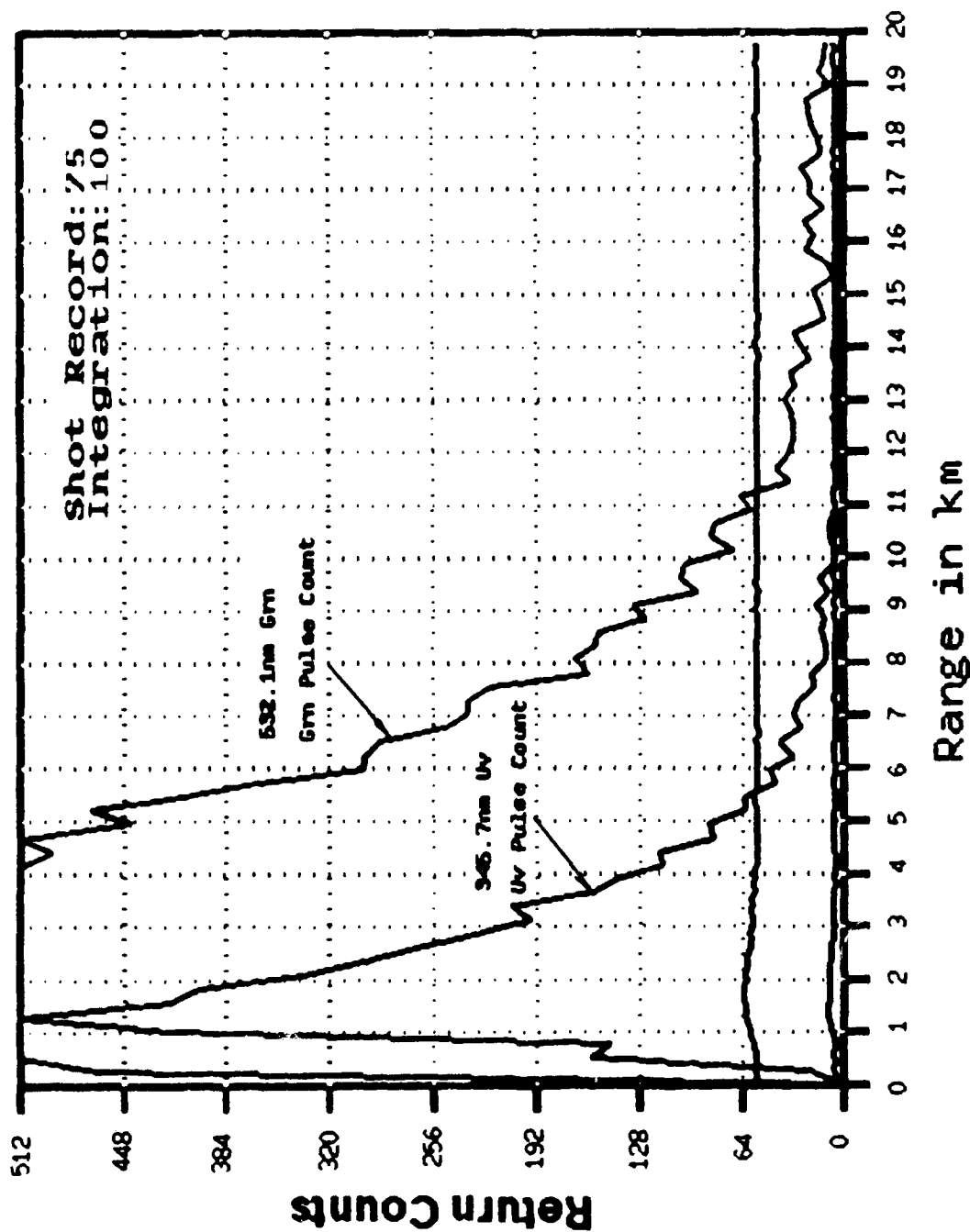


Figure 14. GABLE 90 backscatter data, clear sky.

16 AUG 1990 - 2226

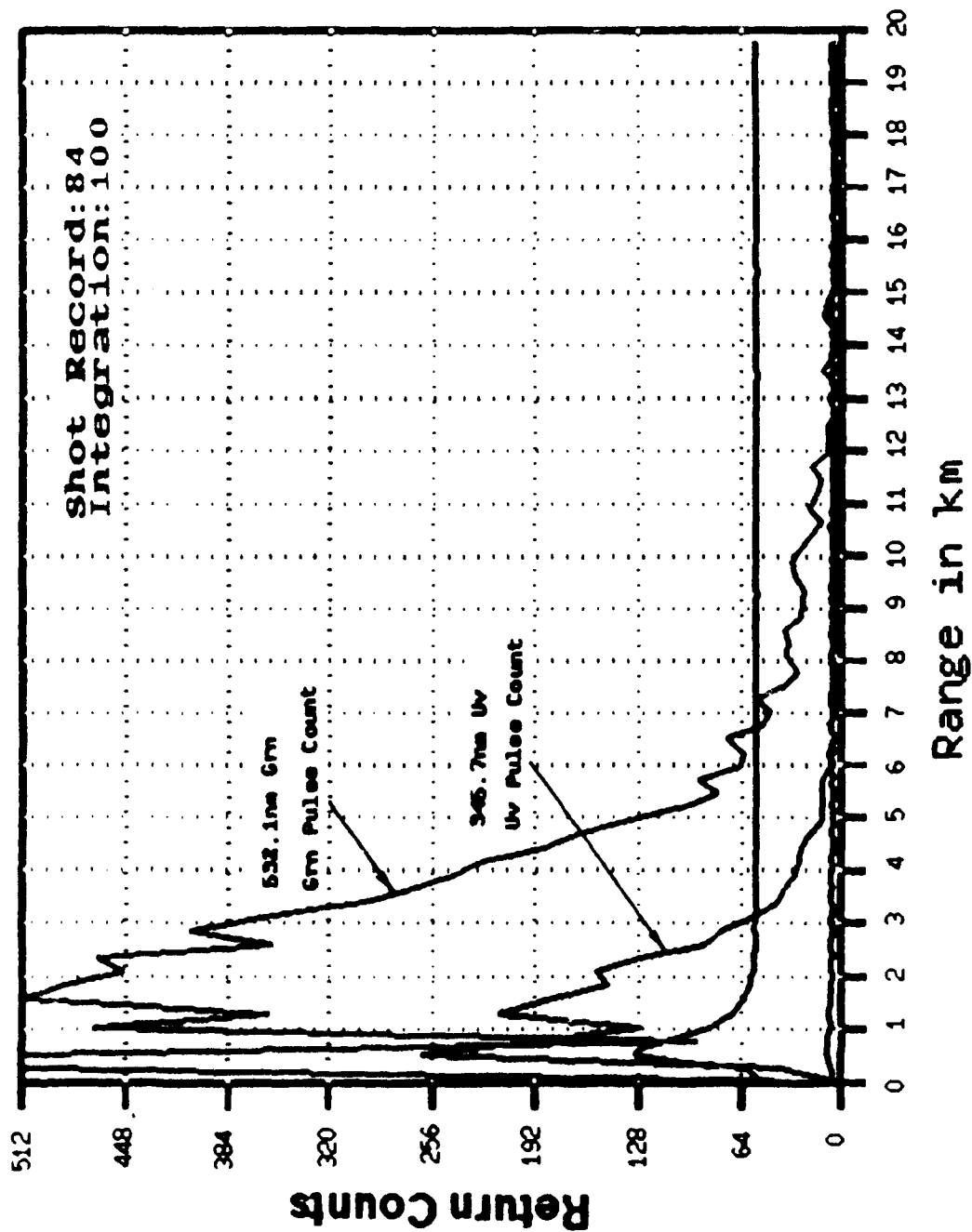


Figure 15. GABLE 90 backscatter data, thin low-level clouds.

6. REFERENCES

1. O. Shepherd, G. Aurilio, R.D. Bucknam, R.W. Brooke, A.G. Hurd, and T.F. Zehnpfennig, "Balloonborne Lidar Experiment", Visidyne, Inc., AFGL-TR-80-0373 (Dec. 1980). ADA095366.
2. O. Shepherd, G. Aurilio, R.D. Bucknam, A.G. Hurd, and W.H. Sheehan, "Project ABLE: Atmospheric Balloonborne Experiment", Visidyne, Inc., AFGL-TR-85-0064 (Mar. 1985). ADA160372.